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EXPERIMENTAL METHODS FOR DETERMINING THE EFFECTIVENESS OF INTERRUPTION OF A FUZE EXPLOSIVE TRAIN

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FOREWORD

There are many different methods that can be used to establish the effectiveness of the interruption of an explosive train. This report describes a series of approaches which, if followed, will make it possible to predict the safety of a given explosive train with a high level of confidence. In addition, by more or less standardizing the method by which the safety of an explosive train is established, one will be able to make a reasonable comparison of the safety of various safety-arming devices.

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ABSTRACT

Several experimental approaches for establishing the effectiveness of the interruption of an explosive train are presented. It is recommended that a combination of the approaches described be used to evaluate the safety of any new explosive train.

CONTENTS

INTRODUCTION

A fuze must be designed so that in the "safe" (unarmed condition it provides an interruption in the explosive train to separate the "sensitive" elements from those elements of the train sufficiently insensitive as to constitute an acceptable hazard. In familiar terminology, the initiation of the primary explosive components must not initiate any of the secondary explosive components beyond the barrier or interrupter. The barrier or interrupter must be at that point in the train at which the explosive output would not reach a level of intensity that would constitute a hazard and at which the explosion must be contained within the fuze case.

An investigation of the safety of an explosive train must take into account the following facts:

1. The output intensity of the initiator or in-line portion of the train can vary within some range. The samples available for testing will usually not approach the extremes of this range.

2. The sensitivity to initiation of explosive components beyond the interrupter can vary within some range.

3. The physical dimensions of all mechanical parts can vary. This includes such items as the thickness of the barrier, the thickness of the fuze case, the cups and end sealing of encapsulated components, and gaps or clearances between parts.

4. The strength, homogeneity, brittleness, and presence of cracks or fissures in barrier materials can vary.

Since a very low probability of safety failure is the objective, none of these variables can be ignored in the attempt to evaluate the safety of an explosive train interruption. Testing and analysis must explore each of these variables. It is also essential to consider each of these aspects of the problem because of the possibility that assumptions regar ing the normalizing function may be significantly in error unless large quantities of test data are available to establish this normalizing functio

EXPERIMENTAL METHODS OF INVESTIGATION

Figure 1 shows the major components of a typical explosive train. The first element is a detonator, or primer, which is responsive to either an electrical or a mechanical input. The second element is the barrier or interrupter, which will prevent the progression of a detonation if the detonator is fired when the barrier is in the "safe" position. The barrier can contain an intermediate charge—either an explosive lead or flash detonator—or merely a hole through which the detonator output can be allowed to reach the third element in the train, when the barrier is in the "armed" position. The third element in the train is generally the output lead. The output lead, booster, and warhead must contain only secondary explosives.

To design tests which will be used to evaluate an explosive train, the first step is to search out the possible failure paths by which the sensitive elements in the train, including any of those in the barrier or interrupter, might directly initiate the output lead, booster, or warhead. Figure 1 indicates five of the possible failure paths, each of which may be investigated by one or more of the techniques described below

PROGRESSIVE ARMING TEST

The objective of the progressive arming test is to determine the safety or effectiveness of the explosive train interrupter as a function of its position. In Figure 1, line "A" indicates this path of initiation, which is generally subjected to a progressive arming test. The test consists of progressively moving the explosive train toward the "armed," or in-line, position, to determine the point at which the sensitive elements will transfer the detonation to the second item in the train. The test is based on the assumption that the probability of initiating the out-of-line component can be expressed as a function of the distance between the two explosive components and that the function is continuous throughout the range of separation from the "armed" position to the "safe" position. Too frequently such a test is performed under the assumption that the relationship between the separation distance (degree of misalignment) and the probability of propagation between the two is a Gaussian distribution. Instances can be found of the firing of Bruceton-type experiments around the 50 percent firing point and of extrapolation of the calculation from this data to the "safe" position without further investigation. Data near the extremes must be taken to permit a Probit analysis or other suitable approach that will increase confidence in the validity of the predictions regarding safety of the unarmed train; and if other points intermediate between "safe" and "armed" are of interest, data

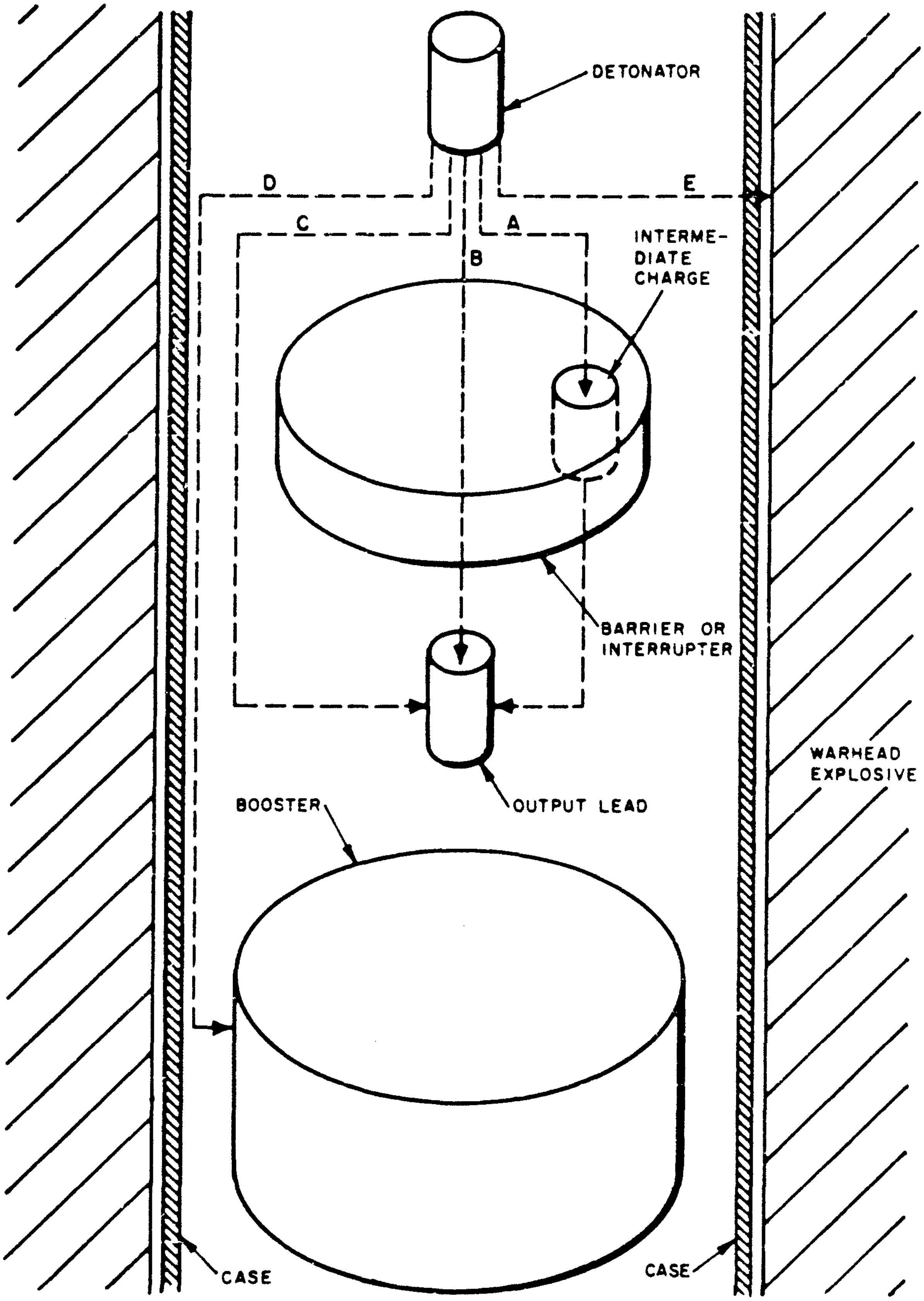

FIGURE 1. Typical Components of a Fuze Explosive Train

must be gathered concerning operation at these points to assure that the assumption of a continuous function is valid.

The methods of conducting the progressive arming test and the statistical methods of evaluating the test data are described in NAVORD Report 2101.[1] The criteria which are used to determine whether any one shot is rated "safe" or "unsafe" need to be carefully established. MIL-STD-315 contains some criteria which should be used; additional criteria will need to be established that give consideration to the specific item being tested.

BARRIER THICKNESS TEST

The purpose of the barrier thickness test is to establish a barrier thickness that will contain the output of the sensitive elements. If the barrier were evaluated at standard barrier thicknesses, the number of tests required would be prohibitive. To reduce the number of tests required, the test may be performed by progressively degrading, or thinning, the barriers. If the barriers are reduced by proper increments, the statistical evaluation described in NAVORD Report 2101 can be used. For example (see Figure 1), the possible failure path P would be explored by progressively reducing the thickness of the barrier, and failure path C would be explored by reducing the length of the path by which the barrier could be circumvented. Other paths such as D and E, which go directly from the detonator to the booster or warhead, would also be investigated by progressively thinning the thickness of the mechanism case, the warhead liner, or other materials between the detonator and the booster or warhead.

INCREASED OUTPUT TEST

The objectives of the increased output test are (1) to provide increased confidence in the results of the progressive arming and barrier thickness tests, and (2) to explore the effects of the detonator variability on the safety of an explosive train. It is possible that the detonators used in the progressive arming and barrier thickness tests did not provide the maximum output that could be encountered. For example, the Mk 71 detonator may have been used in these tests. This detonator, when confined in brass,has an output which results in an average dent of 0.015 inch in a steel dent block. The specification for this detonator (as for

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[1] NAVORD Report 2101, Statistical Methods Appropriate for Evaluation of Fuze Explosive-Train Safety and Reliability (U), by H. P. Culling, Naval Ordnance Laboratory, White Oak, Maryland, 13 October 1953.

most detonators) provides no maximum output requirement—i.e., no specific upper limit on the explosive capability of the detonator. Test data from production lots of the Mk 71 detonator show dent values rang ing through 0.019 inch. To assure that the explosive train is safe when a detonator with a maximum output is encountered, tests should be conducted with a substitute detonator whose output is higher than the output of the detonators which are to be used. In case the Mk 71 detonator is specified, a Mk 70 detonator, which has a specified average dent capability of 0.019 inch, could not be used for test purposes.

At present, detonators are not available in a desirable series of incremental steps of output, but the steps available should be used to confirm the adequacy of the barrier selected by a repetition of the barrier thickness test using detonators of higher output. Designs for a graded series of detonators, varying in useful increments of output, are in preparation and will be available for future use in refined tests of this variable.

INCREASED SENSITIVITY TEST

The objectives of the increased sensitivity test, like the increased output test, are (1) to provide increased confidence in the progressive arming test and the barrier thickness test, and (2) to explore the effect of variability in the sensitivity of the acceptor explosive. To explore any of the possible failure paths indicated in Figure 1, it would be necessary to use explosives of increased sensitivity in the acceptors (lead, booster, or warhead). In some cases it would be impractical to duplicate the complete acceptor with more sensitive explosives; at such time thin layers of sensitive explosive might be used to simulate the acceptor charge.

A useful explosive for this test is PETN. The ratio of the sensitivity of PETN to that of other common secondary explosives, including tetryl CH-6, RDX, and some typical warhead explosives, is known. Further information on the ratios of sensitivity of various explosives is contained in NAVWEPS Report 7411.[2]

[2] NAVWEPS Report 7411, VARICOMP, A Method for Determining Detonation-Transfer Probabilities (U), Naval Ordnance Laboratory, White Oak, Maryland, 30 June 1961.

SUMMARY

The foregoing sections describe tests that may be used to investigate possible failure paths in a fuze explosive train. The descriptions of the tests are necessarily brief because the actual details will depend on the fuze design. An evaluation of a fuze explosive train which made use of the tests outlined above is described in detail in NOLC Report 671.[3] This report not only describes the test procedure in detail but also describes the method of analyzing the data.

[3] NOLC Report 671, WALLEYE Fuze Mk 328 Mod 0 Explosive-Train Tests, by R. L. Higuera and R. L. Smith, Naval Ordnance Laboratory, Corona, California, in publication.

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13 ABSTRACT

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